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## STANDARD ENGINE REPORT ON CURTISS MODEL C-6 AVIATION ENGINE RATED AT 160 HORSE- POWER AT 1750 REVOLUTIONS PER MINUTE

(POWER PLANT SECTION REPORT)

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# STANDARD ENGINE REPORT ON CURTISS MODEL C-6 AVIATION ENGINE RATED AT 160 HORSEPOWER AT 1,750 REVOLUTIONS PER MINUTE.

## OBJECT.

The object of this test was to obtain complete information concerning the design and performance of the Curtiss 6-cylinder model C-6 aviation engine, rated at 160 horsepower at 1,750 revolutions per minute.

## SUMMARY OF TEST RESULTS.

Normal brake horsepower at full throttle, 160.6 brake horsepower at 1,750 revolutions per minute.

Fuel consumption at normal horsepower, 0.500 pound per (actual) brake horsepower-hour.

Oil consumption at normal horsepower; 0.0157 pound per (actual) brake horsepower-hour.

Normal brake mean effective pressure, 126.9 pounds per square inch.

Total weight, dry, 448.5 pounds.

Weight, dry, per normal brake horsepower, 2.792 pounds.

## CONCLUSIONS.

The engine is of a size adapted for training.

The design is not satisfactory for this service without changes to facilitate maintenance.

The performance of the engine was good.

As regards the suitability of this engine for service use, it is well to note that it completed, recently, a 50-hour endurance test, without any forced stops and with minor failures only.

## DESCRIPTION OF THE CURTISS MODEL C-6 AVIATION ENGINE.

### TYPE.

Name.....	Curtiss.
Model.....	C-6.
Serial number of engine tested.....	395 (mfrs).
Number of cylinders.....	6.
Arrangement.....	Vertical.
Drive.....	Direct.
Cooling.....	Water.
Cycle.....	Four stroke.
Fuel.....	Gasoline.
Tractor or pusher.....	Either.
Adapted to cannon.....	No.

### MANUFACTURER.

Curtiss Aeroplane & Motor Corporation, Garden City,  
L. I.

### CHARACTERISTIC FEATURES.

Steel cylinder liners with integral combustion chambers, screwed into aluminum head castings; detachable en bloc aluminum water jackets permitting cooling water in direct contact with the sides of cylinder barrel; two separate cam shafts; four directly driven valves per cylinder;

aluminum alloy bearing bushings with white metal lining for main bearings and connecting rod bearings; wet sump; one Zenith double carburetor; and two Berkshire magnetos with provision for battery excitation in fully retarded position.

NOTE.—The construction of the Curtiss C-6 engine is exactly similar to that of the Curtiss C-12 engine except for a number of features noted below:

#### Crank case (see figs. 6 and 7):

##### Crank-shaft bearings—

Material.....Aluminum alloy bearing bushing lined with white metal.

##### Engine mounting lugs

##### or flanges—

Number.....Eight.

Location.....Four on each side of upper case.

##### Breathers—

Number.....Three.

Location.....In the right-hand upper corner of the transverse webs Nos. 2, 4, and 6.

Construction....Cast in the web.

Oil passages.....From mounting flange through No. 4 web to inside of case supplying oil to main bearings.  
From around No. 1 bearing to upper vertical shaft bearing and directly up to the top of the crank case supplying oil for the cam shafts.

#### Crank shaft (see fig. 8):

Crank-shaft gear retained by one internal key.

#### Connecting rods (see fig. 9):

Type.....Single.

##### Big end bearing—

Material.....Aluminum alloy bearing bushing lined with white metal.

#### Drives (see figs. 11 and 19):

NOTE.—The photograph and drawing show clearly the construction, number of teeth, and rotation of the various drives. Bronze bushings are used for bearings throughout, except that the water pump shaft is equipped with a ball bearing to hold the thrust of the rotor due to the suction of the water lines. The cam-shaft gear is a skew bevel gear and is fastened to the exhaust cam shaft so that it is placed eccentrically within the cam-shaft gear housing.

#### Cooling system (see fig. 15):

##### Water pump—

Number of outlets .....One.

#### Intake manifolds (see fig. 14):

Number.....Two manifolds and one admission tee.

#### Carburetor (see fig. 14):

Number.....One.

Name.....Zenith.

Model.....U. S. 52.

Type.....Double.

Manufacturer.....Zenith Carburetor Co., Detroit, Mich.

##### Materials—

Body.....Aluminum alloy.

Nozzle.....Brass.

Jets.....Brass.

Type or strainer.....Cylindrical wire mesh.

Method or removing strainer.....Integral with brass cover cap.

This carburetor is exactly similar to those used on the 12-cylinder Liberty engine. A description of the Zenith model U. S. 52 carburetor is on page 23 of Engineering Division Report Serial No. 754.

Auxiliaries (see fig. 17):

Air pump—	
Type.....	Single-acting, plunger.
Speed.....	1/14 crank-shaft speed.
Special features.....	A compensating piston to regulate the pressure required by varying compression ratio.

Starter (see fig. 17).

The electric starting motor is mounted on the rear end of the crank case and is a 12-volt, four-pole, series-wound motor, single-wire system. In the gear case of the starting motor is a spur gear reduction and a Bendix drive device. This driving device meshes with the ring gear fastened to the propeller hub. The starter current is furnished by a 12-volt starting battery, and is controlled by an automatic solenoid switch. The "USL" starter furnished with this engine was a type G-27 (Mfr.'s No. 30). It was manufactured by the United States Lighting & Heating Corporation, Niagara Falls, N. Y.

#### METHOD OF TEST.

The engine was connected to an electric cradle dynamometer and the following runs were made in accordance with the standard method which is completely described in Engineering Division Report. Serial No. 1507:

Two full-power runs.

One friction horsepower and compression pressure run.

Two propeller load runs.

One-hour fuel and oil consumption run.

One mixture control run.

One water circulation run through the engine.

One water pump capacity run with free outlet.

Trials to determine starting torque with engine hot and cold.

The temperature of the oil supplied to the bearings was taken between the pressure pump and the main bearings at a flange connection on the left side of the upper half of the crankcase at No. 4 web.

The oil consumption was obtained during the one-hour run. The crank case was nearly filled with oil and the engine was warmed up. Before starting this test the position of the oil gauge was marked. After the test sufficient oil was added to bring the gauge back to this mark. The amount of oil added was taken as the oil consumption for that period.

This engine was given a 50-hour endurance test on the completion of the dynamometer runs, the results of which are incorporated in Air Service Information Circular, Vol. III, No. 272.

#### RESULTS OF TEST.

The test results which appear in this report were obtained from manufacturer's engine No. 395. It must be borne in mind that in laboratory tests it is possible to operate an engine under more favorable conditions than in actual service. The engine under consideration, when installed in an airplane, and run by the average pilot, will not develop the power nor have the fuel economy which

is recorded in the tables and curves in this report. It will be noted that the air temperatures during the various runs averaged 70° F. and, therefore, the power results are perhaps a little lower than would have been obtained at the standard air temperature of 60° F. The power results are not corrected for temperature, as no reliable method is at present available.

The performance tables are on pages 5 to 8. The performance curves are shown in figures 21, 22, 23, and 24.

Referring to the table of efficiency factors on page 5, the air standard efficiency is the theoretical thermal efficiency based on the compression ratio and computed from the following formula, where  $E$  is the efficiency and  $R$  the compression ratio:

$$E = 1 - \left( \frac{1}{R} \right) 0.408$$

The relative indicated efficiency is the ratio of the indicated thermal efficiency to the air standard efficiency.

The relative brake efficiency is the ratio of the brake thermal efficiency to the air standard efficiency.

#### OBSERVATIONS ON TEST.

The performance of this engine during the test was very good, and no trouble of any kind was experienced in operation of the engine. The vibration was about what might be expected from a 6-cylinder engine of this type, but under laboratory conditions it is impossible to obtain reliable observations in regard to vibration as the engine is very rigidly mounted.

Slight oil leakage was noted at the upper end of the housing for the vertical drive to the cam shaft and at the magneto drive-gear housing.

#### INSPECTION AFTER TEST.

At the completion of the standard engine tests the Curtiss model C-6 engine was completely disassembled for inspection. The following is a report on the condition of the various parts:

##### CRANK SHAFT.

Journals Nos. 1, 3, and 5 had slight scores in fillets. All crank pins showed slight uneven wear and circumferential scoring. The taper at the front end of shaft showed poor lapping, some burning, scores along whole length and a rust deposit at the large end. The front end of No. 7 journal was scored probably by the oil ring.

##### PROPELLER HUB.

The remarks about condition of taper on crank shaft also apply to the bore of the propeller hub.

##### BEARINGS.

The bearings were in exceptionally good condition. The white metal in the crank-shaft bearings was slightly worn away around the oil holes. The connecting-rod bearings showed very little wear.

##### PISTONS.

There was only a moderate deposit of carbon on the top of the piston and practically none inside. The skirt

showed wear on the two sides away from the piston pin bosses. Pistons Nos. 1 and 5 had deep circumferential scratches on the skirt.

#### CAM SHAFT.

The rear part of the right cam shaft showed poor machining. There was slight wear on the surface of the cams. The most noticeable feature was the deposit of rust on all steel parts of the cam-shaft assembly.

#### GEARS.

There was a burr on inside of gear teeth of cam-shaft drive gear. The crank-shaft gear showed signs of slight bottoming. The teeth of the ratchet gear for hand starting were badly burred.

#### VALVES.

See figure 18. The intake valves had a heavy deposit of carbon. The following valves leaked when tested with gasoline:

Exhaust:<sup>1</sup>—Nos. 3, 5, 7, 9, 11, 13, 15, 17, 21, 23.

Intake:<sup>1</sup>—No. 22.

All other parts showed normal signs of wear incident to a test of this nature. Some water was found in the oil in the crank case and in the cam-shaft housing.

#### ANALYSIS.

#### DESIGN.

The general design is good and the engine assembly presents a compact, clean-cut appearance. The outstanding feature is the en bloc cylinder construction, which permits cooling water in direct contact with the steel liner or cylinder sleeve, except around the combustion chamber. The method of securing good contact of the liner in the cylinder head proper is particularly good. This contact is made by drawing up the integral stud, in the head of the cylinder sleeve, with a nut inside of the water jacket. To make this type of construction watertight is a difficult problem. A little water was found in the oil in the crank case and the steel parts of the cam-shaft housing were rusted. The leak could not be detected when the water jacket was tested for leakage with the engine cold. After the 50-hour test the Welsh plugs, in the aluminum cylinder jacket, were found to leak water.

The use of aluminum bearing bushings lined with white metal for connecting rod and crank-shaft main bearings was exceptionally successful.

The four valves are so located in the cylinder head that they can not be removed without first removing the valve guides. This makes valve grinding very difficult.

Oil from around No. 1 main bearing is taken to the cam-shaft bearings. An oil hole in the rear cam-shaft bearing support registers with a hole in the cylinder head. As there is no locating dowel pin, this support can be reversed, in which case the cam-shaft bearings will get no oil. This should be corrected by the addition of a dowel pin in the bearing support.

Bronze bushings are used for bearings for the various drive shafts, with the exception of the water pump shaft. These bronze bearings are apt to seize at high engine

speeds. White-metal lining is better than plain bronze but ball bearings are best.

All the thrust of the cam shaft is taken by No. 1 bearing support. This is held by two small studs, which do not appear strong enough to carry the load.

#### ADAPTABILITY TO PRODUCTION.

The engine presents no features which can not be easily handled in quantity production.

#### PERFORMANCE.

The performance of the engine on the dynamometer stand was good. The full-power curve had not peaked at 2,100 revolutions per minute, at which speed the engine developed 190 brake horsepower. The brake mean effective pressure at normal speed of 126.9 pounds per square inch was rather high and was maintained fairly constant, thus indicating a high volumetric efficiency throughout the speed range.

The weight, dry, of 2.792 pounds per normal brake horsepower is not very good, but is due to the use of a 6-cylinder construction. The specific fuel consumption with full throttle was good and was practically constant at 0.500 pound per horsepower at all speeds from 1,200 to 2,100 revolutions per minute. The specific fuel consumption on propeller load operation was less than at full throttle operation from 1,400 to 1,800 revolutions per minute, having its lowest consumption of 0.470 pound per horsepower hour at 1,600 revolutions per minute. At speeds below 1,400 revolutions per minute the specific fuel consumption increased rapidly with reduction of speed. Since an engine in service operates most frequently at partial throttle, the conditions indicated on propeller load from 1,800 to 1,400 revolutions per minute should give very satisfactory results. The oil consumption of 0.0157 pound per (actual) normal brake horsepower hour was excellent.

#### ADAPTABILITY TO AIR PLANE.

This engine provides for straightforward mounting, requiring only two engine bed timbers. It is possible to slide the engine in and out on the bed timbers. The head resistance area is not great.

#### ACCESSIBILITY.

The accessibility of all parts and accessories for adjustment and inspection is exceptionally good. The carburetor and magnetos can be reached for adjustment through openings at the sides of the engine cowling. The spark plugs are placed in the sides of the cylinder and are easily reached for replacements. The water pump and the adjustable oil pressure relief valve can be easily reached for adjustments through openings properly located in the engine cowling.

#### MAINTENANCE.

The construction of the engine is such that overhauling can not be done without a considerable expenditure of time as compared with other engines. For instance, the valves can not be ground without removal of the valve guides, which is an operation requiring special tools and more than average care. Many of the aluminum flanges on the engine are so thin as to be subject to breakage in handling or in drawing up on the bolts.

<sup>1</sup> The valves are numbered from 1 to 24, starting from the rear of the engine. The exhaust valves have odd numbers and the intake valves have even numbers.

**WEIGHTS OF CURTISS MODEL C-6 ENGINE AND PARTS.**

	Weight, pounds.	Percent of total.
Crank-case group, complete, with bearings, studs, nuts, and breathers, including:		
1 upper half.....pounds..	69.5	
1 lower half.....do....	37.5	
Total.....	107.0	23.86
Crank-shaft group, complete, with gear, thrust bearing, oil tubes, etc.....	58.5	13.03
Propeller hub assembly, complete.....	18.0	4.02
Connecting-rod group, including 6 connecting-rod assemblies averaging 3.4 pounds each.....	20.5	4.57
Piston group, including 6 piston assemblies, complete, with rings and pin averaging 2.3 pounds each.....	13.8	3.08
Cylinder group, including 6 cylinder assemblies (in block), complete, with valves, valve springs, and valve guides.....	107.0	23.86
Driving-gear group, including:		
Cam-shaft driveshaft and housing, pounds..	2.4	
Magneto brackets and bolts, magneto couplings, upper and lower vertical drives and housing.....pounds..	14.9	
Oil drive.....do....	.9	
Starter driving gear.....do....	7.5	
Total.....	25.7	5.73
Cam-shaft group, including:		
2 cam shafts, complete, with gears and bearings.....pounds..	14.0	
1 cam-shaft housing, complete.....do....	7.6	
12 cam followers.....do....	3.6	
Total.....	25.2	5.62
Lubrication group, including:		
1 oil-pump assembly.....pounds..	6.2	
Oil manifold and piping.....do....	2.6	
Total.....	8.8	1.96
Cooling system group, including:		
Water pump assembly.....pounds..	3.8	
Water manifolds.....do....	4.0	
Total.....	7.8	1.74
Carburetor and intake group, including:		
1 double carburetor assembly.....pounds..	6.8	
2 intake manifolds and admission tee.....pounds..	11.9	
Total.....	18.7	4.17
Ignition group, including:		
2 magneto assemblies.....pounds..	31.0	
Ignition wires and headers with distributor covers.....pounds..	4.5	
Spark plugs.....do....	2.0	
Total.....	37.5	8.36
Total weight, without auxiliaries.....	448.5	100.00
Auxiliaries:		
1 battery for starting.....pounds..	10.5	
1 air pump.....do....	3.0	
1 starter, complete.....do....	19.5	
Total.....	33.0	
Total weight of engine, with auxiliaries.....	481.5	
Weight of water in engine.....	18.5	

**TABLE OF DIMENSIONS.**

NOTE.—All dimensions not shown are the same as the Curtiss model C-12 engine.

General:

Bore.....	4.500 in.
Stroke.....	6.000 in.
Compression ratio.....	5.4:1.
Gear ratio.....	Direct drive.
Rotation of propeller (facing propeller).....	Counterclockwise.
Total piston displacement.....	.572.4 cu. in.
Approximate head resistance area.....	3.92 sq. ft.
Firing order.....	1-5-3-6-2-4.
Method of numbering cylinders.....	From the gear end.

Crank case:

Distance between centers of cylinders—	
Nos. 1-2.....	.5.187 in.
Nos. 2-3.....	.6.000 in.
Nos. 3-4.....	.5.187 in.
Nos. 4-5.....	.6.000 in.
Nos. 5-6.....	.5.187 in.

Diameter main bearing studs—

Inside rows.....	.7/16 in.
Outside rows.....	.3/8 in.

Capacity of oil sump.....5 U. S. gallons.

Main crank-shaft bearings—

No.	Diam- eter.	Length.	Dia- meter clearance.	End clearance.	Projected area.
1.....	Inches. 2.752	Inches. 2.031	Inches. .002	Inches. .031	Square inches. 5.590
2-4-6.....	2.752	1.375	.002	.125	3.784
3-5.....	2.752	2.188	.002	.125	6.020
7.....	2.752	3.094	.002	.312	8.515
8.....	2.752	1.750	.002		4.816

Engine hold-down bolts—

Number.....	8.
Diameter.....	.3/8 in.

Crank shaft:

No.	Outside diam- eter.	Length.	Dia- meter, bore.
Main journals—	Inches.	Inches.	Inches.
1.....	2.750	2.062	2.250
2-4-6.....	2.750	1.500	2.250
3-5.....	2.750	2.313	2.250
7.....	2.750	3.406	2.250
8.....	2.750	2.062	2.250
Crank pins—			
1-2-3-4-5-6.....	2.500	2.145	1.938

Crank cheeks.....Width, 3.500 in.; thickness, 0.750 in.

Thrust bearing—

Type.....Single row, ball.

Number of balls.....10.

Diameter of balls.....0.625 in.

Diameter of ball circle.....4.000 in.

Manufacturer and number.....Hess-Bright No. 6215.

Length of shaft from front end to first crank cheek.....17.312 in.

Propeller hub:

Diameter hub body.....2.625 in.

Length between flanges—

Maximum.....6.000 in.

Minimum.....4.625 in.

Diameter bolt circle.....6.750 in.

Number of bolts.....8.

Diameter of bolts.....0.500 in.

Area of bearing surface on shaft taper.....43.50 sq. in.

Connecting rods:

Length, center to center.....10.000 in.

Rod-stroke ratio.....1.667:1.

Piston pin bushing—

Length.....1.562 in.

Diameter, inside.....1.125 in.

Projected area.....1.757 sq. in.

Clearance to pin.....0.001 in.

End play of rod on pin.....0.188 in.

## Connecting rods—Continued.

Big end bearing—	
Length.....	2.125 in.
Diameter.....	2.502 in.
Number of bolts.....	4.
Minimum diameter of shank (bolts).....	0.311 in.
Thread (bolts).....	3/8", 24 threads per inch.

## Clearance on crank pin—

Diametral.....	0.002 in.
End.....	0.020 in.

Projected area on crank pin..... 5.315 sq. in.

## Cylinders:

Bore.....	4.500 in.
Stroke.....	6.000 in.
Stroke-bore ratio.....	1.333:1.
Piston displacement per cylinder.....	.95.40 cu. in.
Total piston displacement of engine.....	.572.4 cu. in.
Compression volume of cylinder.....	21.68 cu. in.
Total volume of cylinder.....	117.08 cu. in.
Compression ratio.....	5.4:1.
Per cent compression.....	18.52.

## Cam shaft:

Outside diameter.....	0.975 in.
Bore diameter.....	0.688 in.

## Valve timing:

	Designed.	Actual.
Inlet—		
Opens.....	15° early.....	18° early.
Closes <sup>3</sup> .....	26° late.....	24° late.
Exhaust		
Opens.....	50° early.....	46° early.
Closes <sup>4</sup> .....	5° late.....	11° late.

## Carburetor:

Number.....	1 double.
Material, body.....	Aluminum alloy.
Rated size.....	.52 mm.
Diameter at the flange inside.....	1 $\frac{1}{2}$ in.
Chokes, diameter.....	1.106 in.
Metering jets, material.....	Brass.
Diameter, main.....	.54 drill size.
Diameter, compensator.....	.52 drill size.

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*Efficiency factors for Curtiss Model C-6 aviation engine at normal speed of 1,750 R. P. M.*

Cubic inches of piston displacement per brake horsepower .....	3.565
Brake horsepower per cubic inch of piston displacement.....	.281
Brake horsepower per cubic foot of piston displacement.....	485.0
Brake horsepower per square foot of piston area.....	242.5
Piston speed in feet per minute.....	1,750
Indicated mean effective pressure... pounds per square inch..	145.3
Friction mean effective pressure.....do.....	18.4
Brake thermal efficiency <sup>1</sup> .....per cent..	24.20
Indicated thermal efficiency <sup>1</sup> .....do.....	27.72
Air standard efficiency.....do.....	49.74
Relative indicated efficiency.....do.....	55.75
Relative brake efficiency.....do.....	48.67
Mechanical efficiency .....	87.25
Weight per cubic inch of piston displacement.....pounds..	.784

POWER PLANT WEIGHT BY CLASS OF SERVICE  
(POUNDS).<sup>2</sup>

Weight factors.	Pursuit. <sup>3</sup>	Two-place. <sup>4</sup>	Training. <sup>5</sup>
Engine weight, dry.....	452.5	452.5	452.5
Power plant constant weight.....	112.1	112.1	112.1
Cooling system .....	104.3	104.3	104.3
Tankage.....	58.4	95.4	73.2
Fuel.....	150.6	203.1	200.5
Oil.....	36.7	36.7	36.7
Total.....	920.6	1,067.1	979.3
Per horsepower.....	5.732	6.645	6.098

Altitude.	Horse-power(see curve, fig. 23.)	Fuel consumption (pounds per hour).
Sea level.....	160.6	80.3
10,000 feet.....	104.7	56.5
15,000 feet.....	80.6	46.6

<sup>1</sup> Heat content of fuel, 21,000 British thermal units per pound.<sup>2</sup> For explanation of items, etc., see Engineering Division Report, Serial No. 1506, p. 25a et seq.<sup>3</sup>  $\frac{3}{4}$  hour at sea level,  $2\frac{1}{2}$  hours at 15,000 feet.<sup>4</sup>  $\frac{1}{2}$  hour at sea level, 4 hours at 10,000 feet.<sup>5</sup>  $2\frac{1}{2}$  hours at sea level.

## FIRST FULL-POWER RUN.

Positions of altitude control. <sup>1</sup>	R. p. m.	Actual—		Corrected—		Water.		Oil.		Carb. air temp. °F.	Carb. vac., in. hg.	Man. vac., in. hg.	Fuel cons.				
		Brake load, lb.	Brake horse- power.	Torque, lb.-ft.	Horse- power.	B. m. e. p., lb. per sq. in.	In.	Temp. °F.	Temp. °F.				Sec. for 3 lb.	Lb. per hp.- hr.	Lb. per hr.		
		In.	Out.	Sump.	Bear- ings.	In.	Out.	Temp. °F.	Temp. °F.				Sec. for 3 lb.	Lb. per hp.- hr.	Lb. per hr.		
3	1,250	267	111.3	476.7	113.5	125.6	145	160	72	132	82	75	0.5	176.2	0.551	61.3	
3	1,350	267	120.2	476.7	122.6	125.6	141	157	72	135	83	76	.6	187.0	.481	57.8	
3	1,450	267	129.1	476.7	131.6	125.6	143	161	73	139	88	76	.7	155.8	.537	69.3	
3	1,550	270	139.5	482.2	142.3	127.1	144	161	72	140	89	76	.8	161.6	.479	66.8	
2	1,670	273	152.0	487.5	155.1	128.5	138	155	72	145	88	75	1.0	143.4	.496	75.4	
1.5	1,770	270	159.4	482.2	162.6	127.1	145	162	75	149	88	74	1.1	1.2	134.4	.504	80.4
1.5	1,870	268	165.7	475.0	169.1	125.2	142	158	77	151	90	74	1.3	1.4	129.6	.503	83.3
0	1,990	260	172.5	464.5	175.9	122.4	145	160	77	153	92	73	1.4	1.5	124.0	.505	87.2
0	2,070	255	175.9	455.4	179.5	120.0	143	158	77	159	91	74	1.5	1.6	118.6	.517	91.0

Average barometer, 29.33 in. hg.

## SECOND FULL-POWER RUN.

Positions of altitude control. <sup>1</sup>	R. p. m.	Actual—		Corrected—		Water.		Oil.		Carb. air temp. °F.	Carb. vac., in. hg.	Man. vac., in. hg.	Fuel cons.				
		Brake load, lb.	Brake horse- power.	Torque, lb.-ft.	Horse- power.	B. m. e. p., lb. per sq. in.	In.	Temp. °F.	Temp. °F.				Sec. for 3 lb.	Lb. per hp.- hr.	Lb. per hr.		
		In.	Out.	Sump.	Bear- ings.	In.	Out.	Temp. °F.	Temp. °F.				Sec. for 3 lb.	Lb. per hp.- hr.	Lb. per hr.		
4.5	1,250	267	111.2	476.8	113.4	125.6	141	162	72	127	89	75	0.6	180.4	0.539	59.9	
3	1,350	265	119.2	473.1	121.5	124.6	144	165	72	132	89	76	.6	186.2	.487	58.1	
3	1,470	268	131.3	478.5	133.9	126.1	141	163	72	137	91	76	.8	155.6	.529	69.5	
3	1,540	266	135.6	475.0	139.3	125.2	140	158	72	139	91	76	.8	169.0	.468	63.9	
2	1,670	274	152.5	489.1	155.5	128.8	144	163	72	142	91	75	1.0	1.1	143.2	.495	75.5
2	1,770	270	159.3	482.0	162.5	127.0	142	159	75	145	92	75	1.1	1.2	134.8	.503	80.2
1.5	1,870	268	167.0	478.5	170.4	126.1	143	158	75	148	93	75	1.3	1.4	128.8	.502	83.9
0	1,970	262	172.1	467.7	175.5	123.2	144	160	77	151	93	74	1.4	1.5	124.8	.503	86.6
0	2,060	255	175.2	455.3	178.7	119.9	142	158	77	152	94	73	1.5	1.6	121.2	.509	89.1

<sup>1</sup> Altitude control has 10 equal divisions: 0—full rich position; 10—full lean position.

Average barometer, 29.33 in. hg.

## FIRST PROPELLER LOAD RUN.

R. p. m.	Actual—		Corrected—		Water.		Oil.		Carb. air temp. °F.	Carb. vac., in. hg.	Man. vac., in. hg.	Fuel cons.			
	Brake load, lb.	Brake horse- power.	Torque, lb.-ft.	Horse- power.	Temp. °F.	Temp. °F.	Press., lb. per sq. in.	Sec. for 3 lb.				Lb. per hp.- hr.	Lb. per hr.		
	In.	Out.	Sump.	Bear- ings.	In.	Out.	Temp. °F.	Temp. °F.				Sec. for 3 lb.	Lb. per hp.- hr.	Lb. per hr.	
1,770	269	158.7	480.6	161.8	145	159	75	136	103	73	1.1	1.2	136.4	0.499	79.2
1,660	240	132.8	428.5	135.5	141	158	73	142	88	73	.7	3.7	172.2	.473	62.8
1,550	212	109.5	378.5	111.7	145	161	73	143	82	74	.5	5.8	204.4	.483	52.9
1,450	184	88.9	328.4	90.7	145	160	73	141	78	74	.4	7.8	237.6	.511	45.4
1,340	161	72.0	287.5	73.5	147	162	72	138	77	76	.3	9.6	279.6	.537	38.6
1,240	138	57.1	246.4	58.3	144	158	72	133	78	77	.2	11.2	325.8	.581	33.2

Average barometer, 29.33 in. hg.

## SECOND PROPELLER LOAD RUN.

R. p. m.	Actual—		Corrected—		Water.		Oil.		Carb. air temp. °F.	Carb. vac., in. hg.	Man. vac., in. hg.	Fuel cons.			
	Brake load, lb.	Brake horse- power.	Torque, lb.-ft.	Horse- power.	Temp. °F.	Temp. °F.	Press., lb. per sq. in.	Sec. for 3 lb.				Lb. per hp.- hr.	Lb. per hr.		
	In.	Out.	Sump.	Bear- ings.	In.	Out.	Temp. °F.	Temp. °F.				Sec. for 3 lb.	Lb. per hp.- hr.	Lb. per hr.	
1,790	271	161.7	483.1	164.6	145	161	81	135	104	61	1.1	1.2	134.2	0.498	80.5
1,660	238	131.7	424.4	134.1	143	158	77	142	88	60	.8	3.9	174.2	.471	62.0
1,550	208	107.5	370.9	109.5	141	160	77	143	81	60	.6	6.0	207.4	.485	52.1
1,460	184	89.6	328.0	91.3	144	159	77	141	78	61	.4	7.7	238.8	.505	45.3
1,340	162	72.4	288.8	73.7	146	160	75	137	78	62	.3	9.7	276.0	.541	39.2
1,240	131	54.2	233.3	55.2	144	157	73	132	78	63	.2	11.7	287.8	.693	37.6

Average barometer, 29.39 in. hg.

NOTE.—Altitude control set 0.2 full lean position for both runs.

## ONE-HOUR FUEL AND OIL CONSUMPTION RUN.

R.p.m.	Actual—		Corrected—			Water		Oil.			Carb. air temp. °F.	Carb. vac., in. hg.	Man. vac., in. hg.	Fuel cons.		Oil cons.				
	Brake load, lb.	Brake horse- power	Torque, lb.-ft.	Horse- power.	B. m. e. p., lb. per sq. in.	Temp. °F.		Temp. °F.		Press., lb. per sq. in.				Lb. for 5 min.	Lb. per hp.-hr.	Lb. for 60 min.	Lb. per hp.-hr.			
						In.	Out.	Sump.	Bear- ings.											
1,782	268	160.9	477.3	163.6	125.7	141	156	80	135	108	62	1.1	1.2	6.75	0.503					
1,770	271	160.4	482.4	163.1	127.1	146	161	77	142	92	62	1.1	1.2	6.75	.505					
1,752	272	158.8	484.1	161.5	127.6	144	159	77	148	85	62	1.1	1.2	6.50	.492					
1,766	272	160.2	484.1	162.8	127.6	145	161	77	149	84	62	1.1	1.2	6.75	.506					
1,762	272	159.6	484.1	162.3	127.6	144	160	77	149	82	62	1.1	1.2	6.50	.489					
1,762	271	159.2	482.4	161.8	127.1	145	161	77	150	80	62	1.1	1.2	6.50	.490					
1,766	272	160.1	484.1	162.7	127.6	142	158	77	150	80	62	1.1	1.2	6.75	.506					
1,768	271	159.8	482.4	162.5	127.1	143	159	77	150	80	62	1.1	1.2	6.50	.488					
1,760	271	159.1	482.4	161.7	127.1	144	160	77	150	81	62	1.1	1.2	6.75	.509					
1,766	271	159.2	482.4	162.2	127.1	143	160	77	150	81	62	1.1	1.2	6.50	.489					
1,756	271	158.5	482.4	161.3	127.1	143	159	77	150	81	62	1.1	1.2	6.50	.492					
1,744	270	157.0	480.5	159.6	126.6	143	159	77	149	81	62	1.1	1.2	6.75	.516					

## AVERAGE RESULTS FOR ONE HOUR.

1,763	271	159.2	482.4	161.3	127.1	144	160	77	148	84	62	1.1	1.2	179.50	0.500	2.50	0.0157
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<sup>1</sup> Total for 60 minutes.

Note.—Altitude control set 0.2 full lean position.

Average barometer, 29.42 in. hg.

Data for all runs:

Length of brake arm, 21 inches.

Kind of oil used, 50 per cent castor, 50 per cent Mobiloil "B".

Specific gravity of gasoline, 0.710 at 60°F.

MIXTURE CONTROL RUN.<sup>1</sup>

## FULL RICH SETTING.

Positions of altitude control.	R. p. m.	Actual—		Corrected—			Water.		Oil.			Carb. air temp. °F.	Man. vac., in. hg.	Carb. vac., in. hg.	Gas. cons.				
		Brake load, lb.	Brake horse- power	Torque, lb.-ft.	Horse- power.	B. m. e. p., lb. per sq. in.	Temp. °F.		Temp. °F.		Press., lb. per sq. in.				Sec. for 3 lb.	Lb. hp. hr.			
							In.	Out.	Sump.	Bear- ings.									
Full rich....	1,780	274	162.5	491.1	166.4	129.4	145	160	75	134	103	70	1.2	1.1	1.4	129.2	0.515		
Do.....	1,570	218	113.1	387.0	115.7	102.0	146	162	73	136	89	70	5.8	.5	1.2	181.0	.528		
Do.....	1,250	140	58.3	250.9	59.7	66.1	146	158	72	132	73	70	11.3	.3	.9	303.2	.611		

## BEST SETTING.

( <sup>1</sup> ) 1.5 div.....	1,790	273	162.9	489.4	166.8	128.9	145	160	77	145	85	70	1.2	1.1	1.6	131.2	0.505
Full lean....	1,560	212	110.3	379.9	112.9	100.1	144	160	75	140	81	70	5.8	.5	1.7	219.6	.446
Full lean....	1,240	140	57.9	250.9	59.3	66.1	148	160	72	129	81	70	10.1	.3	2.0	363.4	.513

## FULL LEAN SETTING.

Full lean....	1,770	215	126.8	385.3	129.9	101.5	150	162	75	147	84	70	1.2	1.1	5.4	172.6	0.494
Do.....	( <sup>2</sup> )	137	58.9	245.5	60.3	64.7	148	160	72	126	84	70	10.2	.2	20	361.1	.508
Do.....	1,290	137	58.9	245.5	60.3	64.7	148	160	72	126	84	70	10.2	.2	20	361.1	.508

<sup>1</sup> Speed and load adjusted as for propeller load operation.<sup>2</sup> Just cracked open.<sup>3</sup> Could not run at 1,550 r. p. m. as engine missed and back-fired.

Average barometer, 29.22 in. hg.

## FRICTION HORSEPOWER AND COMPRESSION PRESSURE RUN.

Engine, r. p. m.	Corrected engine, b. h. p. <sup>1</sup>	Friction load, lb.	Friction horse- power.	Per cent mech. eff.	Temperatures °F.				Comp. Press., lb. per sq. in. <sup>2</sup>	B. m. e. p., lb. per sq. in.		
					Water.		Oil.					
					In.	Out.	Sump.	Bear- ings.				
1,250	113.5	31	12.9	89.8	145	147	93	143	1	100	14.3	
1,350	123.5	33	14.9	89.3	145	147	97	143	2	100	15.3	
1,450	133.0	35	16.9	88.7	145	147	99	143	3	101	16.1	
1,550	142.5	37	19.1	88.2	145	147	99	145	4	100	17.0	
1,650	152.0	39	21.5	87.6	145	147	100	146	5	102	18.0	
1,750	160.5	40	23.3	87.3	145	147	102	146	6	100	18.4	
1,850	168.0	42	25.9	86.7	145	147	104	146	.....	.....	19.4	
1,950	174.0	44	28.6	85.9	145	147	99	148	.....	.....	20.3	
2,050	178.3	47	32.1	84.8	145	147	95	149	.....	.....	21.7	

<sup>1</sup> Corrected engine brake horsepower taken from curve in fig. 21.<sup>2</sup> Compression pressure taken at 120 revolutions per minute.

Average barometer, 29.33 in. hg.

Average air temperature, 72° F.

## STARTING TORQUE.

Throttle position.	Engine cold.				Engine warm.				
	Starting torque, lb.-ft.				Starting torque, lb.-ft.				
	1	2	3	Average.	1	2	3	Average.	
Open.....	108.5	122.5	113.7	114.9	Open.....	87.5	92.8	92.8	91.0
Closed.....	103.3	103.3	89.3	98.6	Closed.....	105.0	115.5	105.0	108.5

## WATER PUMP CAPACITY RUN THROUGH ENGINE.

Engine, r. p. m.	Water temp. ° F.	Gross lb. (tank + water).	Weight.		Flow, in sec.	Gal. per min. <sup>1</sup>		Venturi reading, in. hg.	Gallons per min. <sup>2</sup>	
			Can, lb.	Net, lb. (water).		Actual.	Aver- age.		Actual.	Average.
1,250	73	158.0	43.0	115.0	30	27.64	27.32	{ 1.60	27.95	{ 28.38
1,250	74	155.0	42.5	112.5	30	27.00	27.00	{ 1.70	28.82	{ 28.38
1,450	76	171.5	43.0	128.5	30	30.85	30.98	{ 2.15	32.37	{ 32.58
1,450	79	172.5	43.0	129.5	30	31.10	30.98	{ 2.20	32.80	{ 32.58
1,650	69	183.5	43.0	140.5	30	33.74	34.58	{ 2.70	36.34	{ 36.65
1,650	70	190.5	43.0	147.5	30	35.42	34.58	{ 2.80	36.97	{ 36.65
1,850	75	217.0	42.5	174.5	30	41.90	40.04	{ 3.50	41.32	{ 40.41
1,850	73	202.0	43.0	159.0	30	38.18	38.18	{ 3.20	39.50	{ 40.41
2,050	78	214.5	42.5	172.0	30	41.30	43.22	{ 3.80	43.05	{ 42.78
2,050	82	230.5	42.5	188.0	30	45.13	45.13	{ 3.70	42.50	{ 42.78

<sup>1</sup> By weight.<sup>2</sup> By venturi.

Barometer, 29.17 in. hg.

## WATER PUMP CAPACITY RUN—FREE INTAKE AND DISCHARGE.

Speed, r. p. m.	Drive torque, <sup>1</sup> lb.-ft.		Drive horse- power	Flow.	
	Pump.	Engine.		Sec. for 200 lbs.	Gallons per minute.
1,875	1,250	1.45	0.518	29.0	49.7
2,175	1,450	1.60	.662	26.2	55.0
2,475	1,650	1.70	.801	22.6	63.8
2,775	1,850	1.85	.978	20.6	70.0
3,075	2,050	2.10	1.230	19.0	75.9

<sup>1</sup> 12-inch arm.

NOTE.—Maximum pressure at normal engine speed of 1,750 revolutions per minute is 12 pounds per square inch.

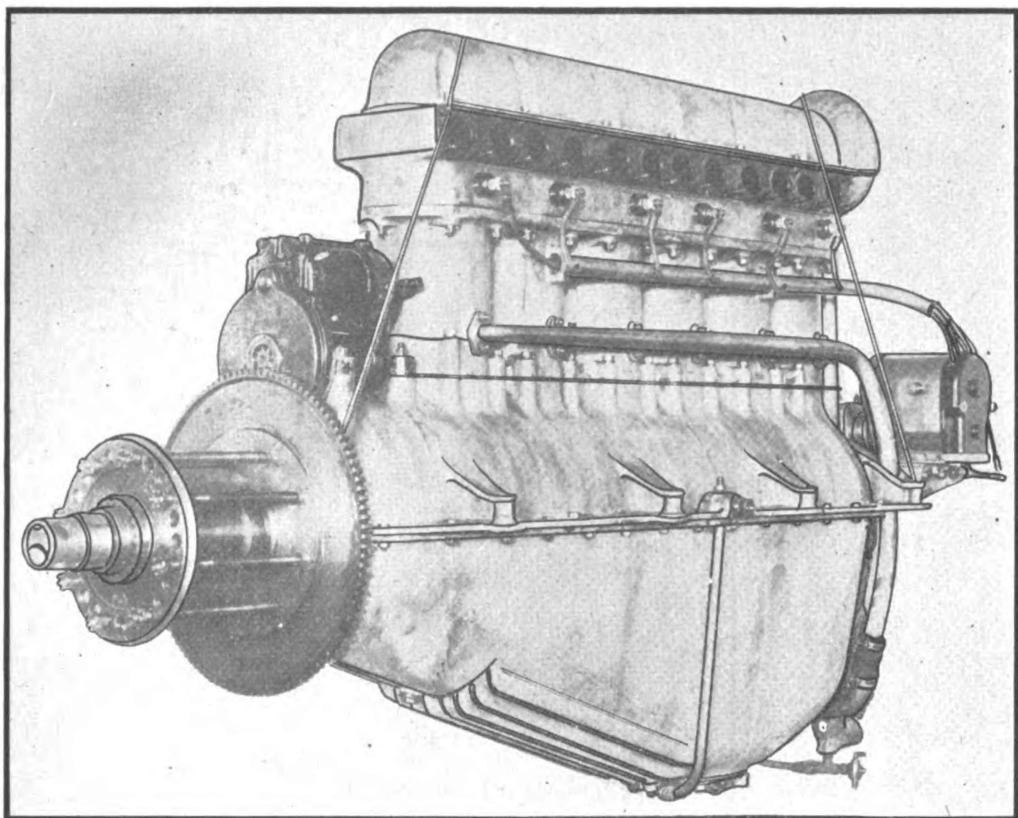


FIG. 1.—Three-quarter front view (left side).

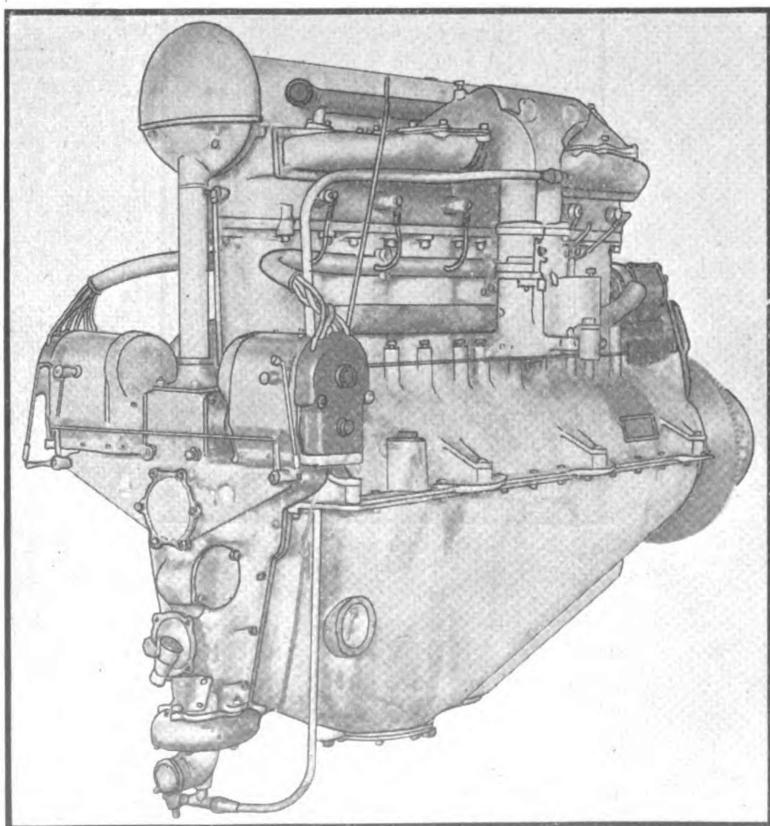


FIG. 2.—Three-quarter rear view (right side).

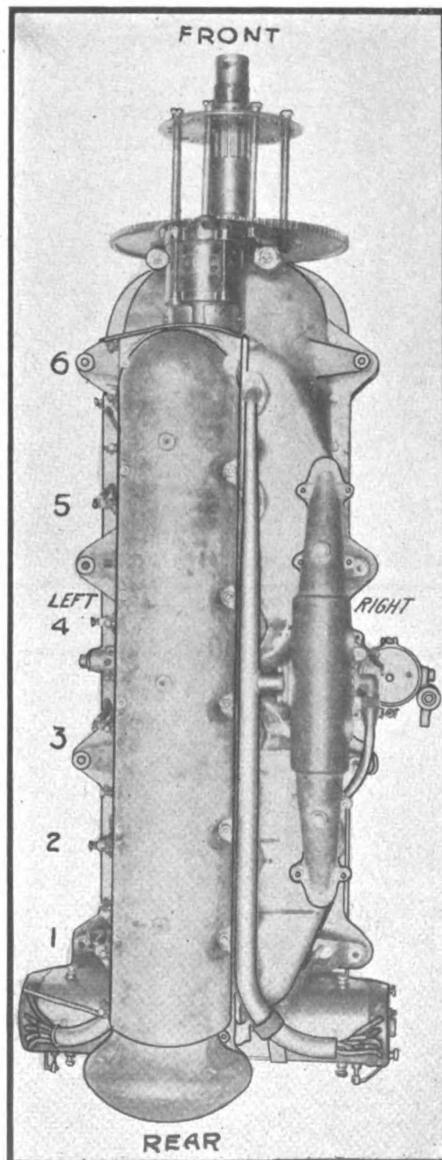


FIG. 3.—Top view.

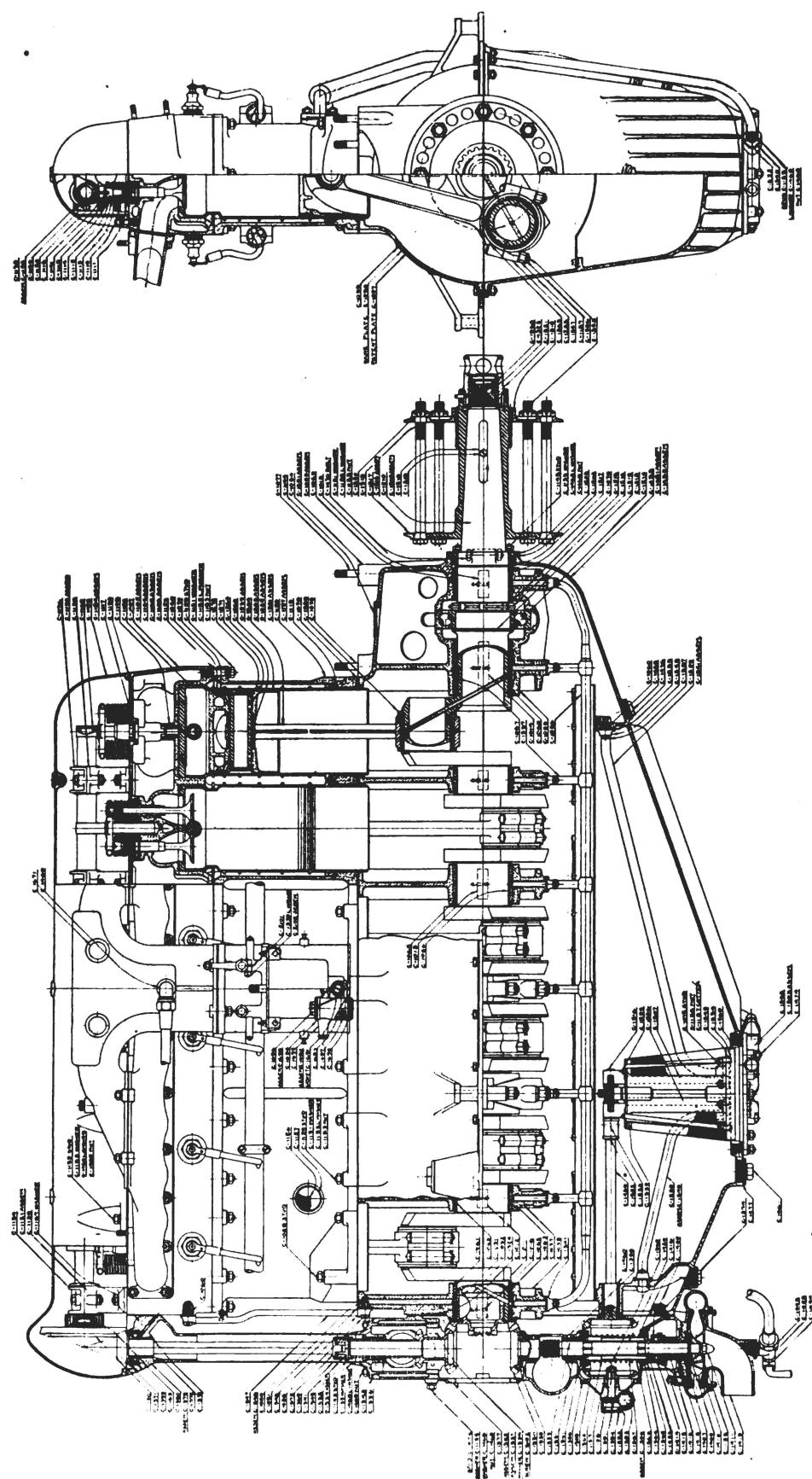


FIG. 4.—Propeller end view and longitudinal section.

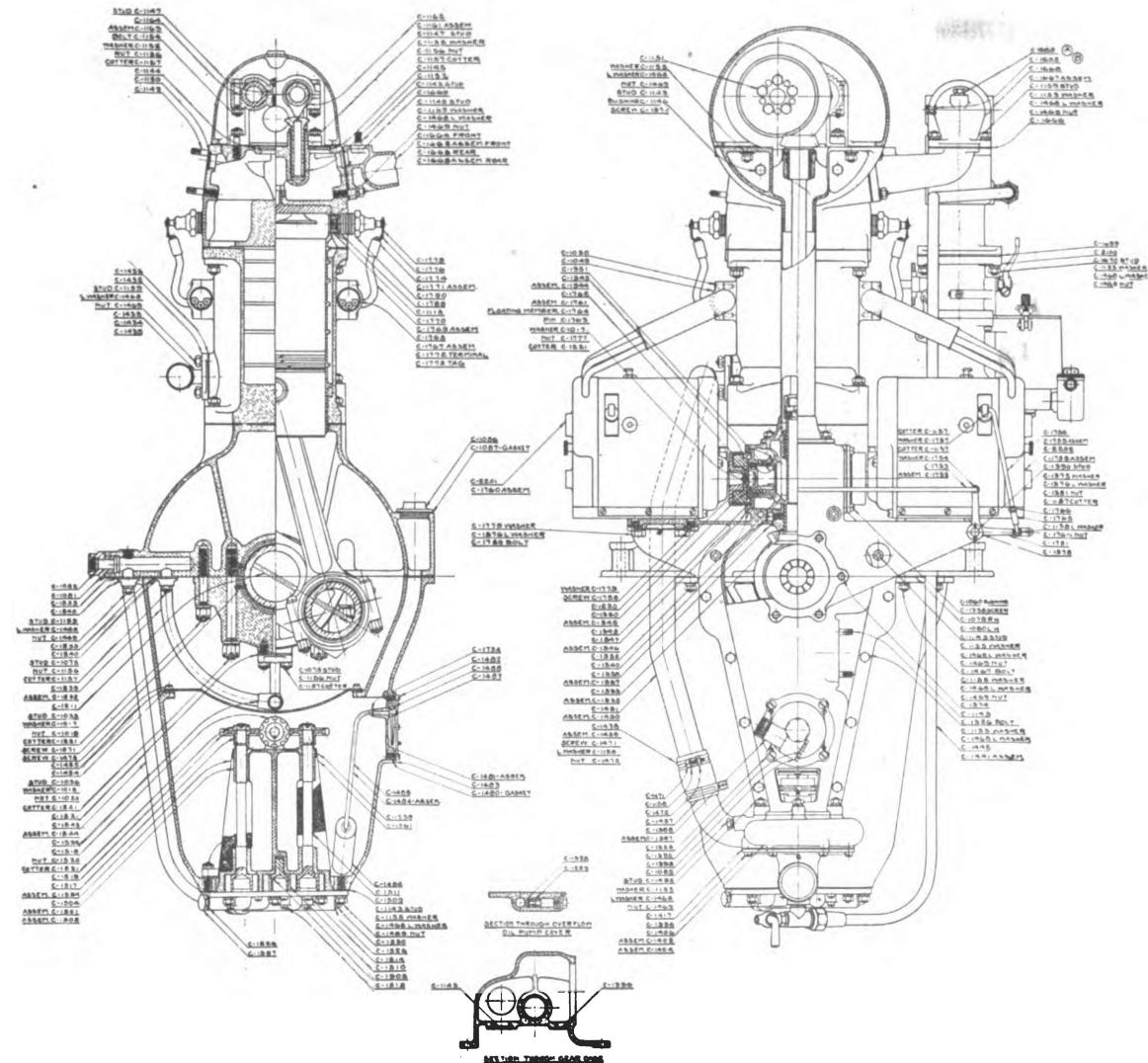


FIG. 5.—Gear end view and transverse section.

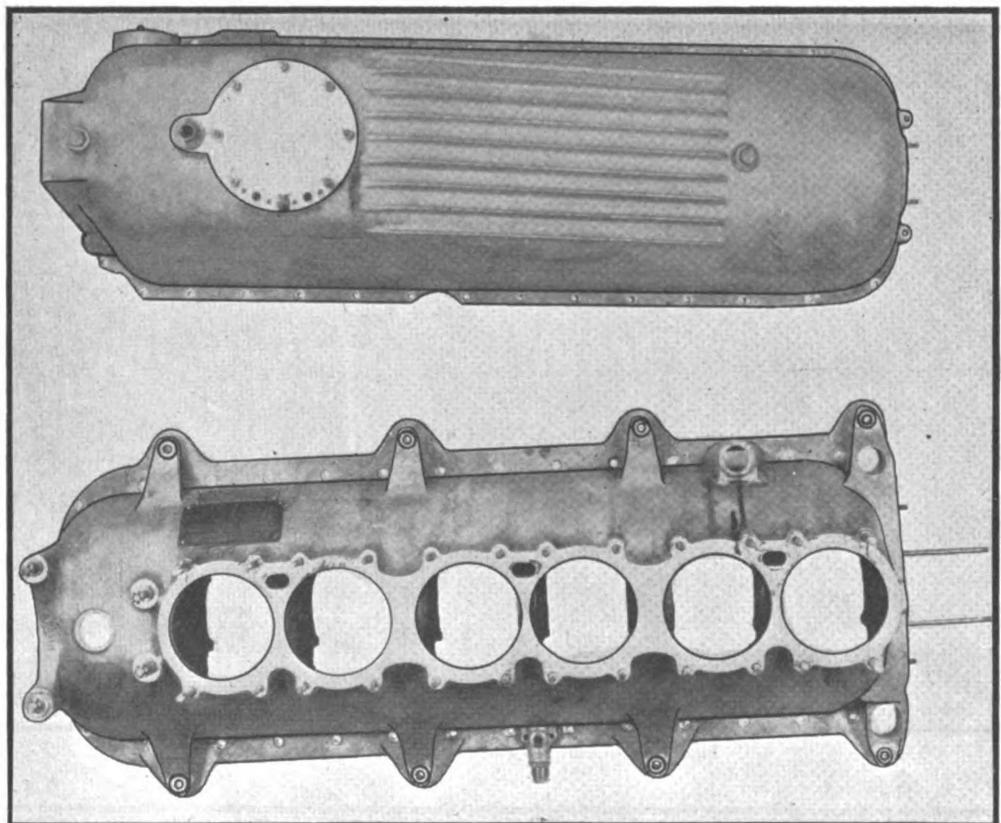


FIG. 6.—Crankcase, upper and lower halves, outside views.

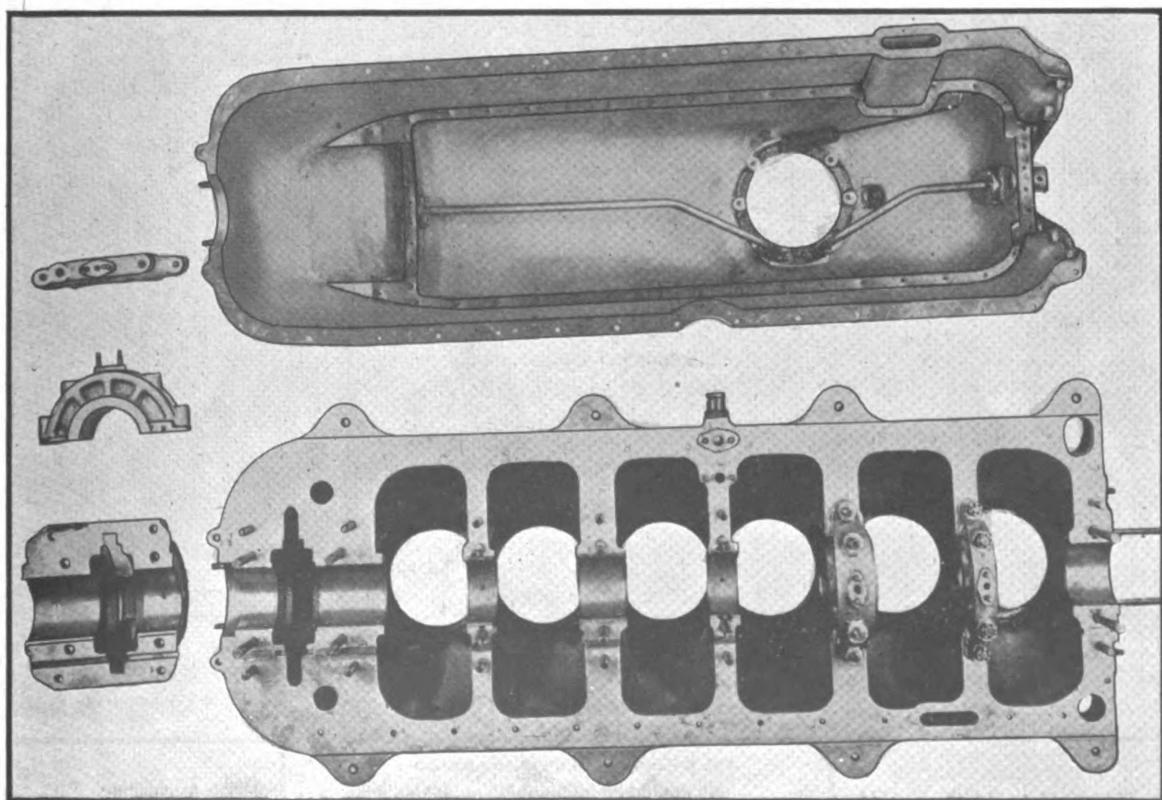


FIG. 7.—Crankcase, upper and lower halves, inside views.

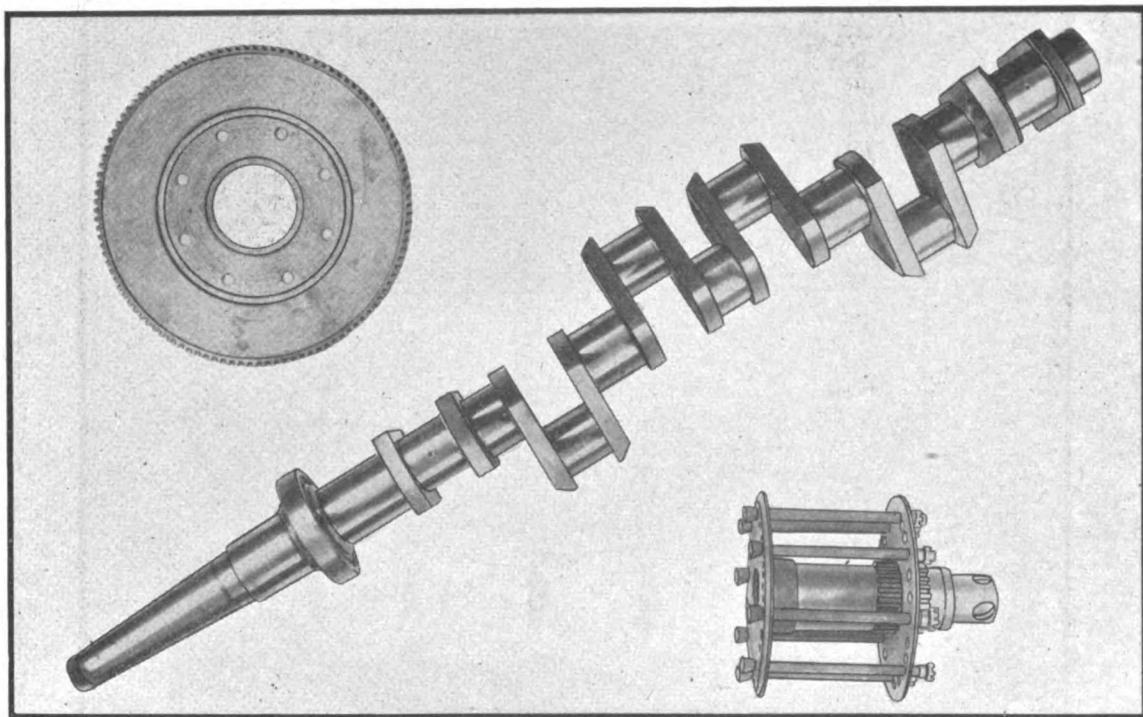


FIG. 8.—Crankshaft, propeller hub, and starting gear.

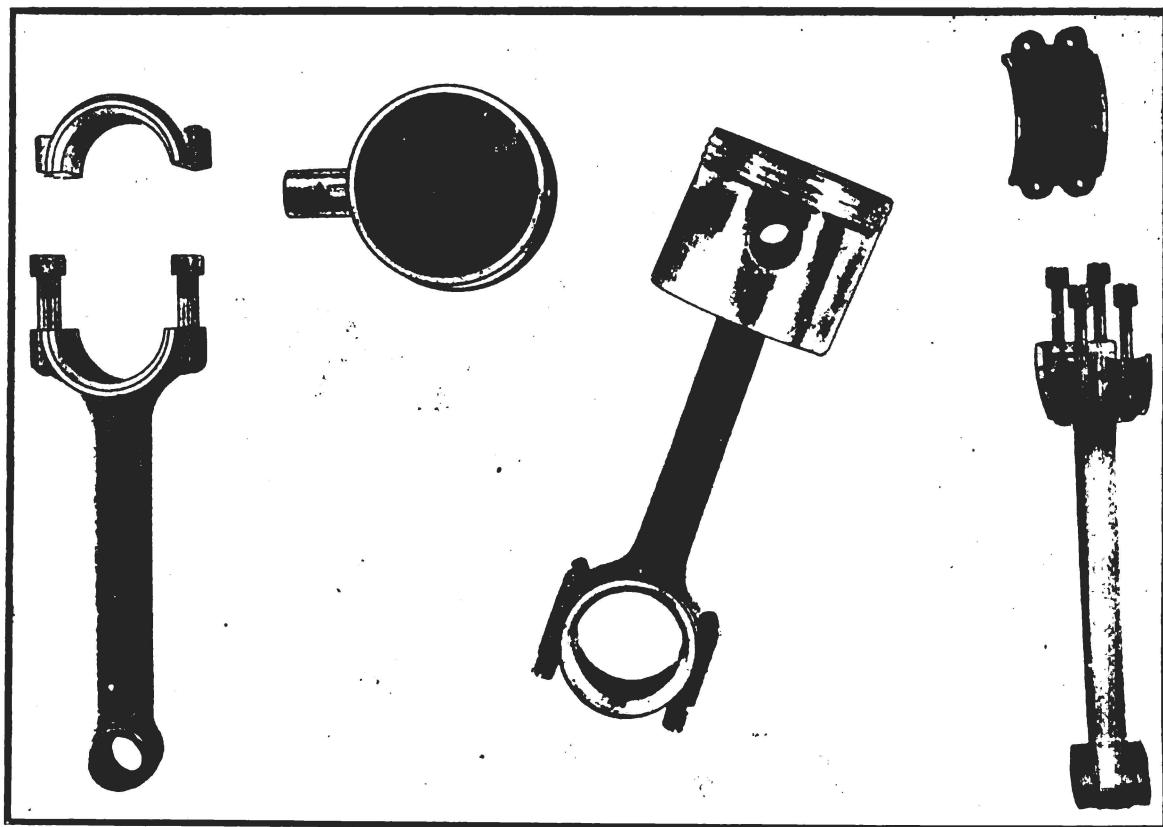


FIG. 9.—Pistons and connecting rods.

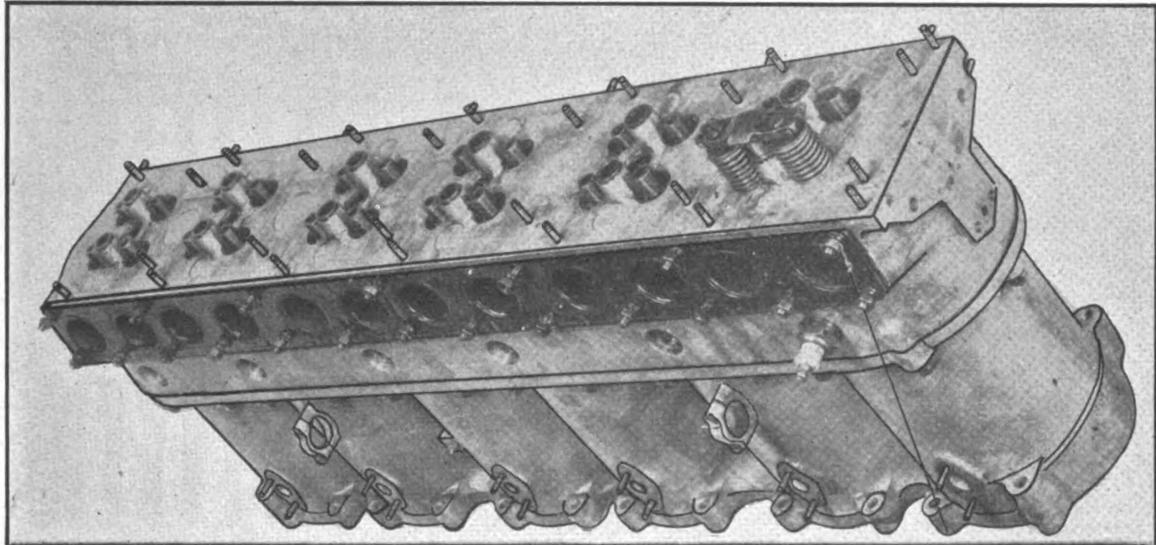


FIG. 10.—Cylinder block assembly.

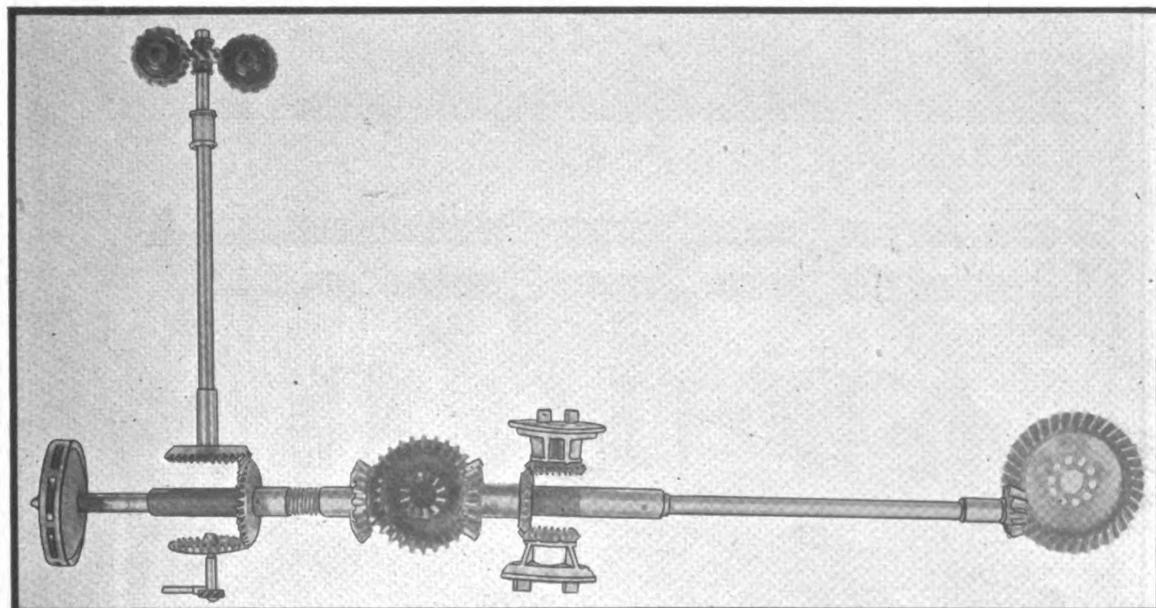


FIG. 11.—Drives laid out according to location in engine.

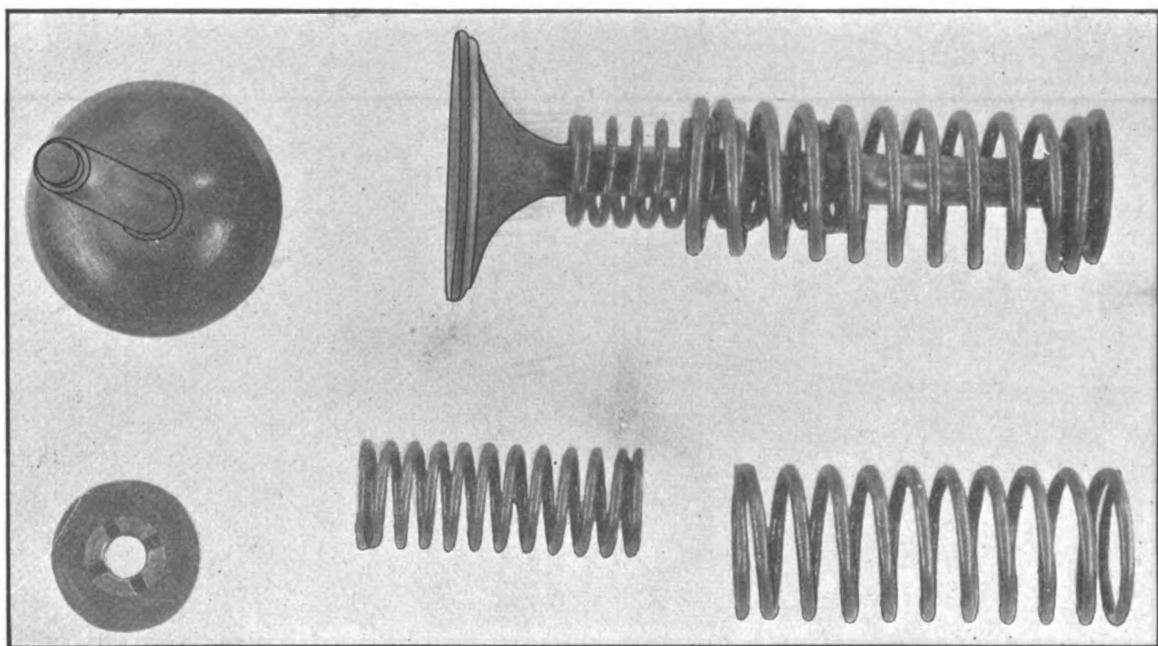


FIG. 12.—Valves and valve springs.

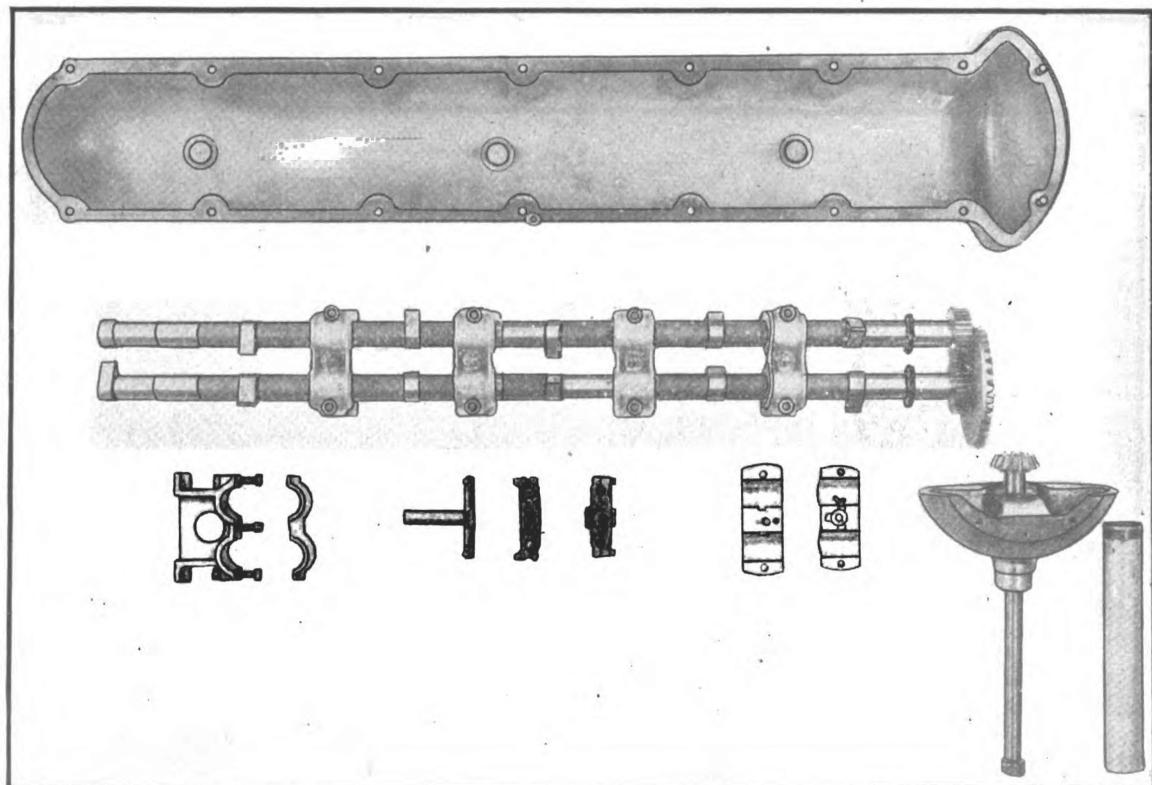


FIG. 13.—Camshafts and housing.

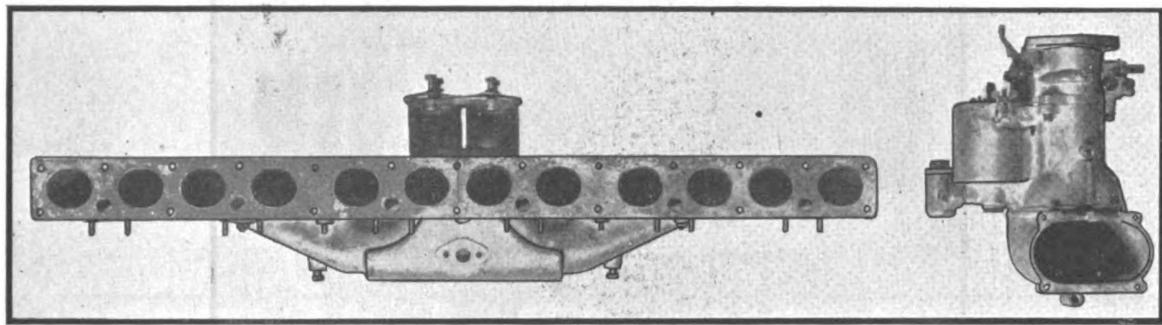


FIG. 14.—Carburetor and intake header.

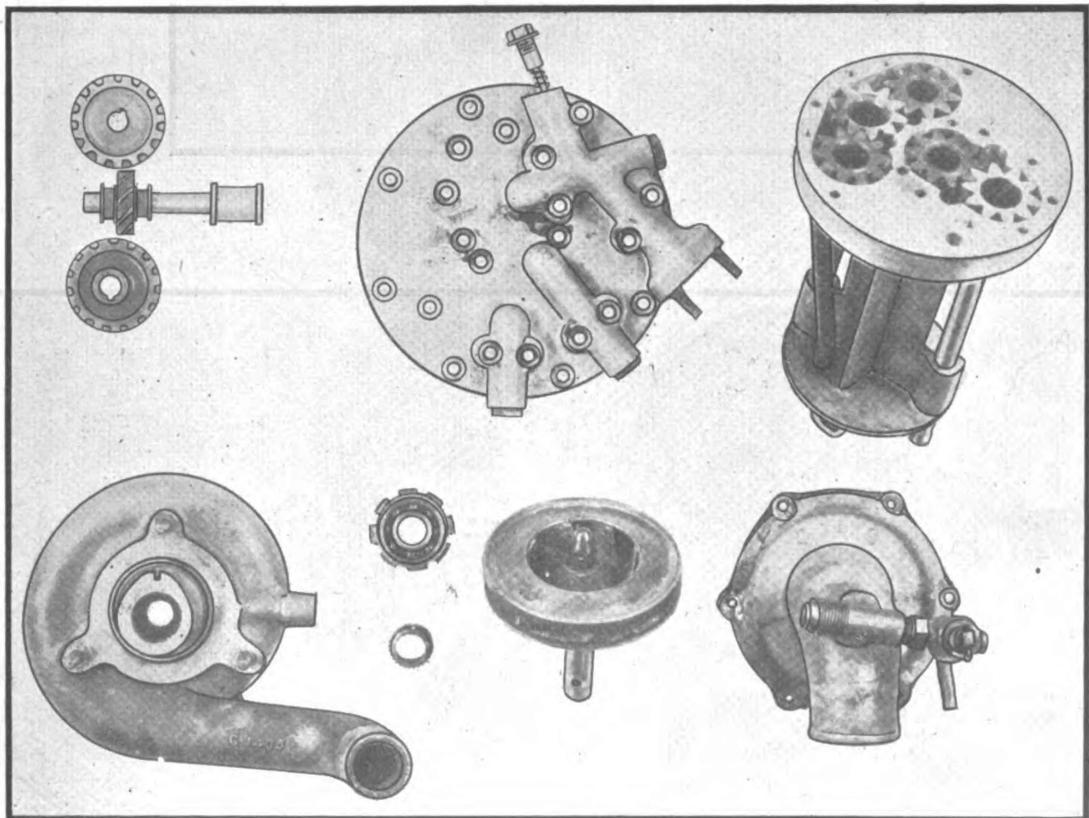


FIG. 15.—Water pump and oil pumps.

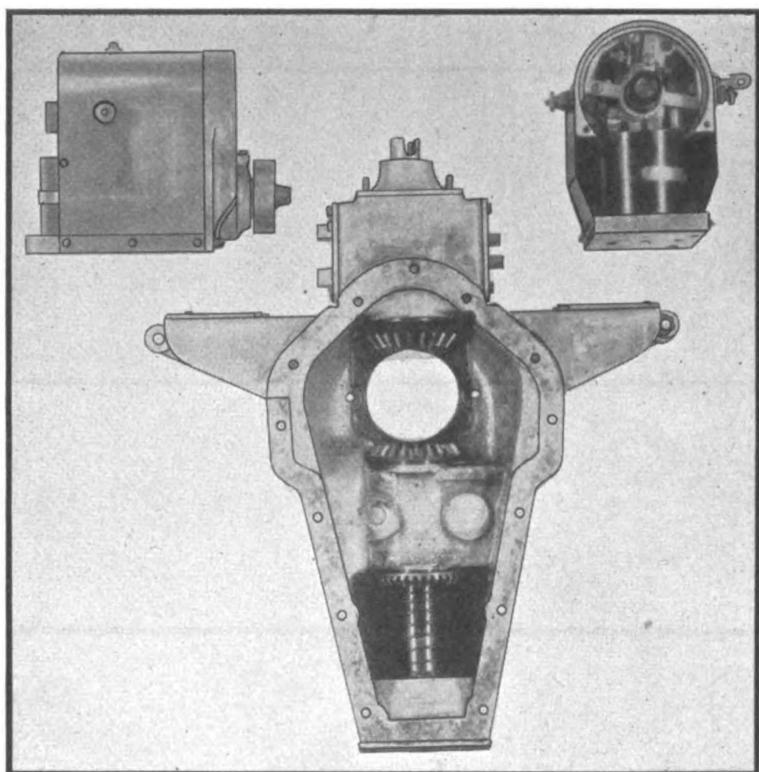


FIG. 16.—Gear case and magnetos.

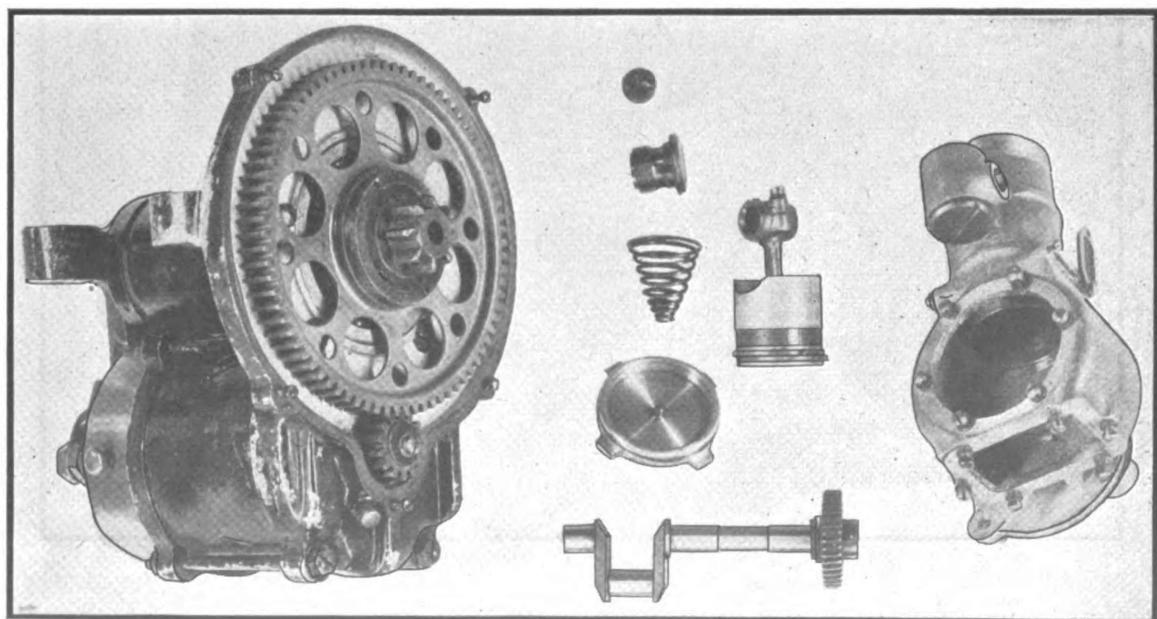


FIG. 17.—Starter and air pump.

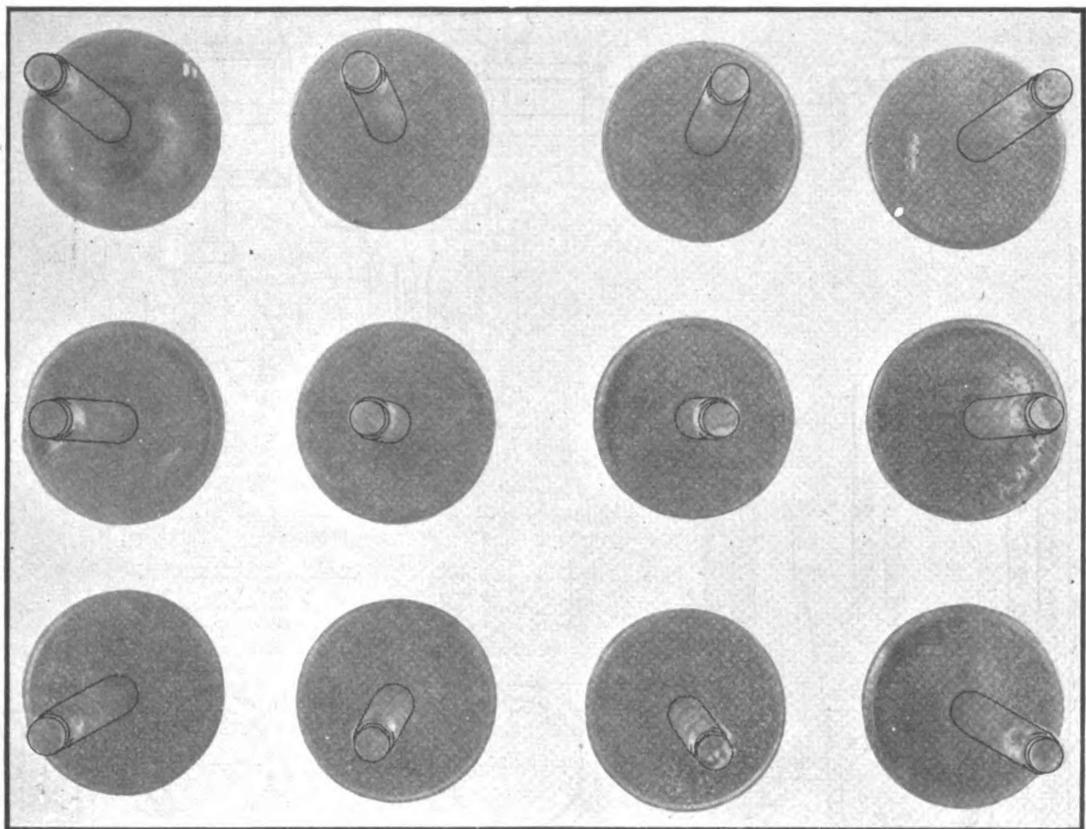


FIG. 18.—Intake valves after test.

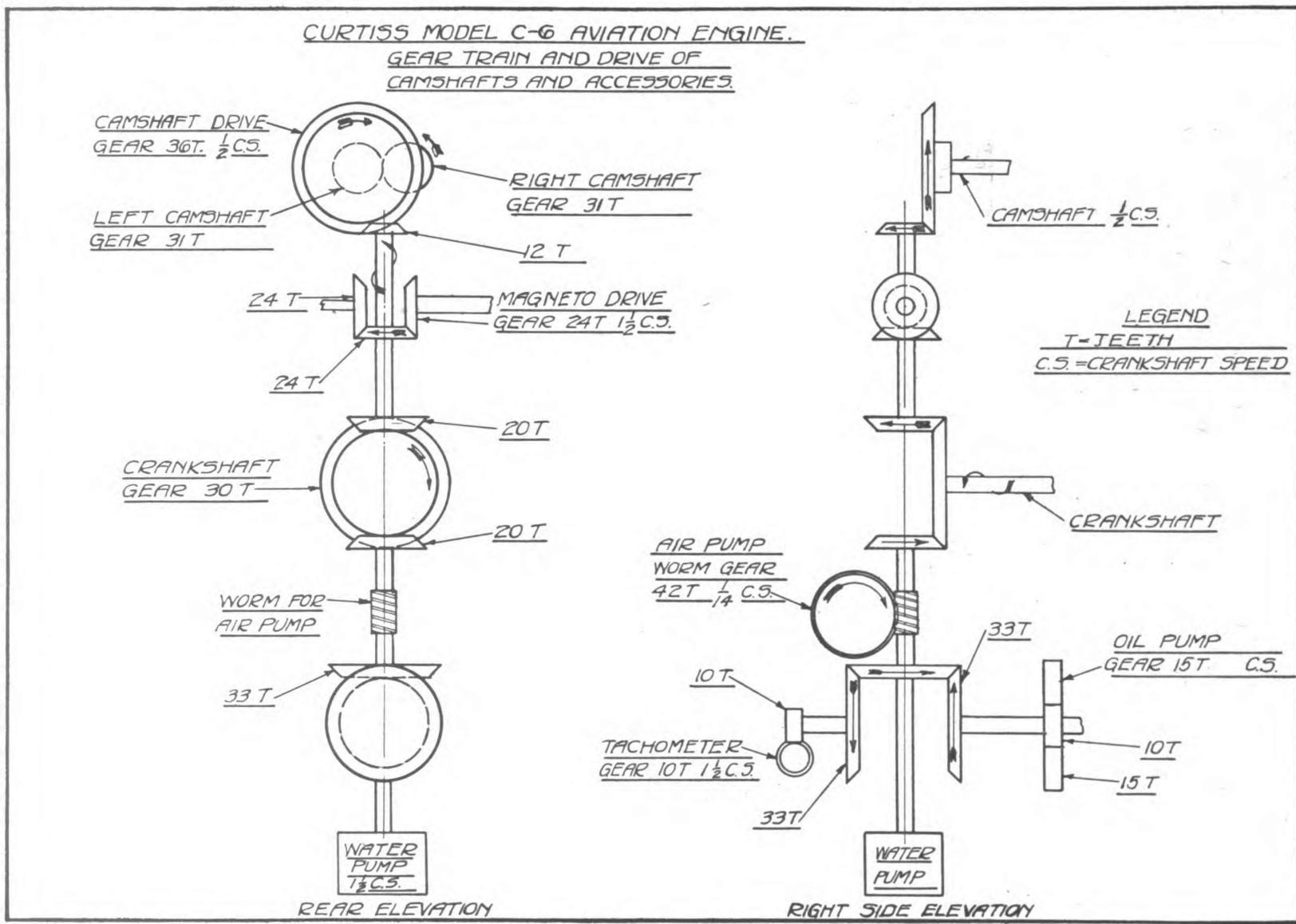


FIG. 19.

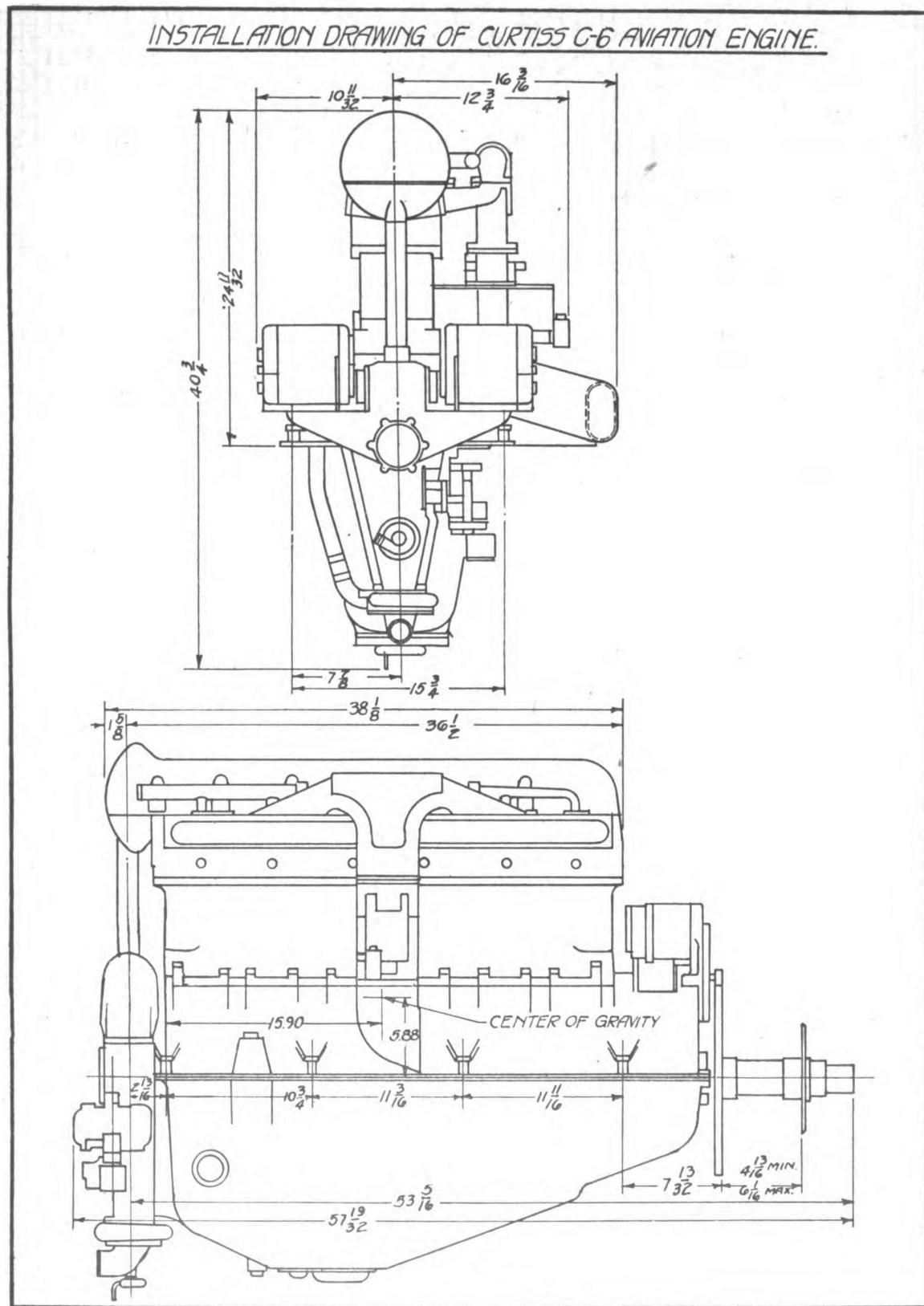


FIG. 20.

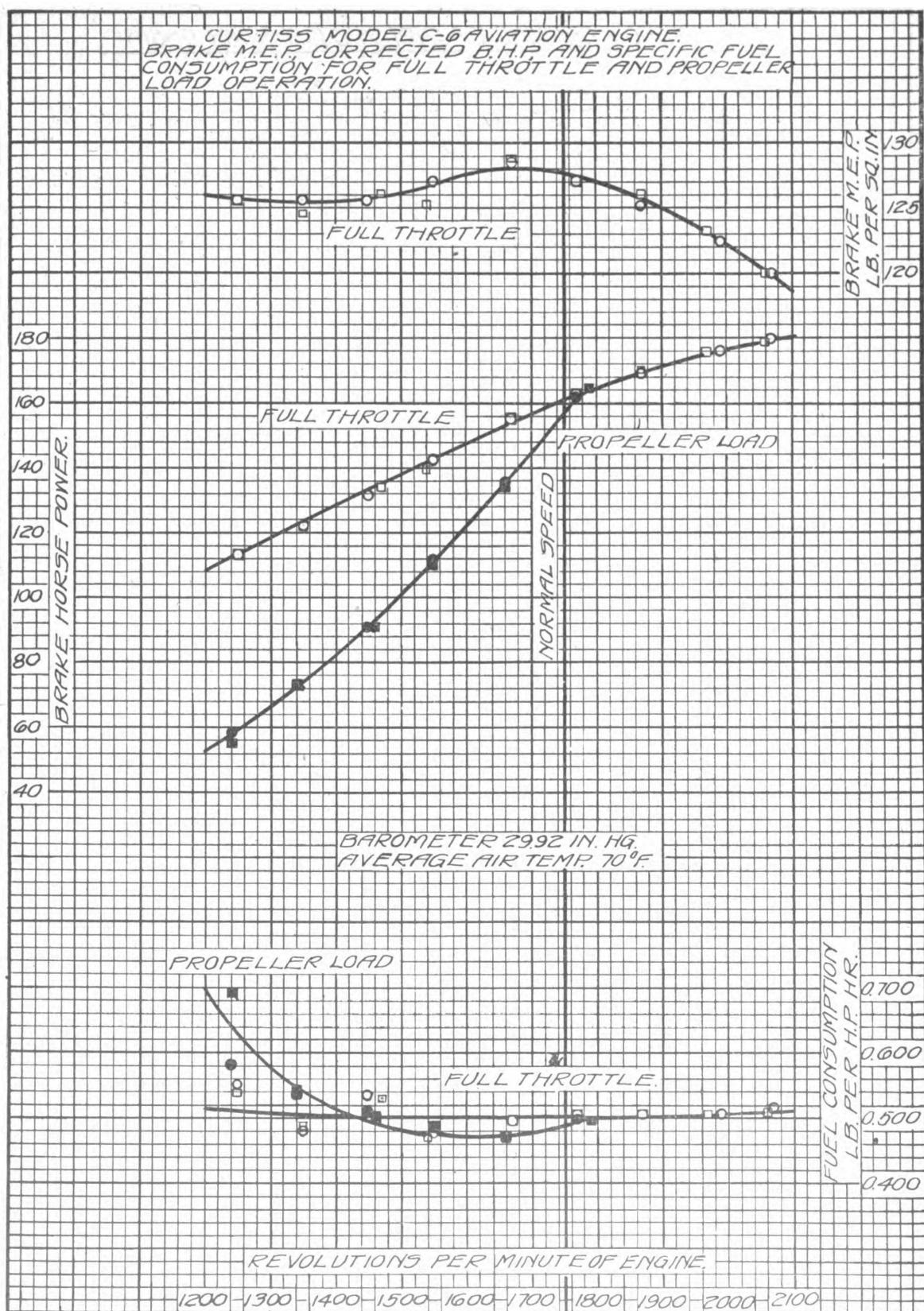


FIG. 21.

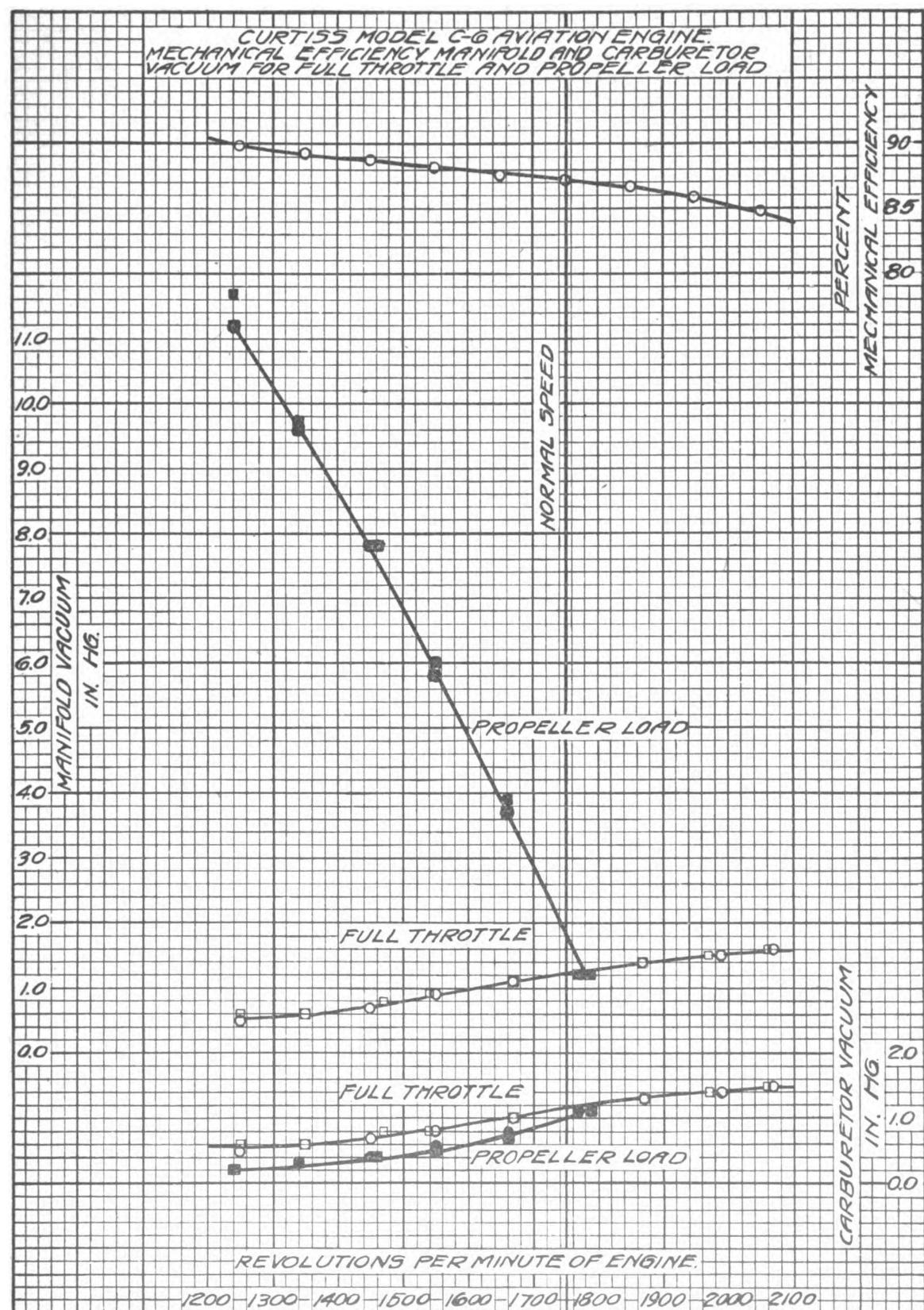


FIG. 22.

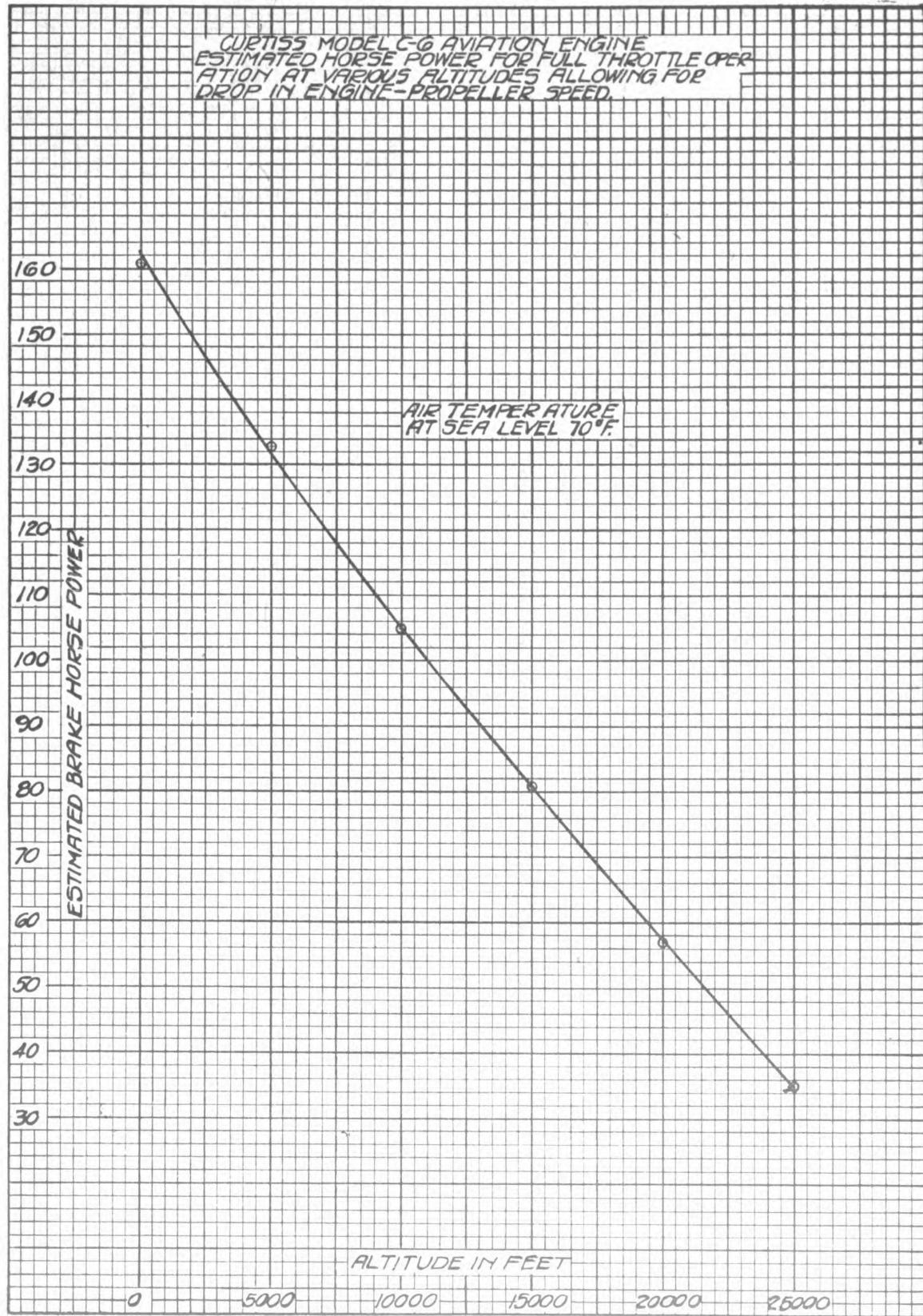


FIG. 23.

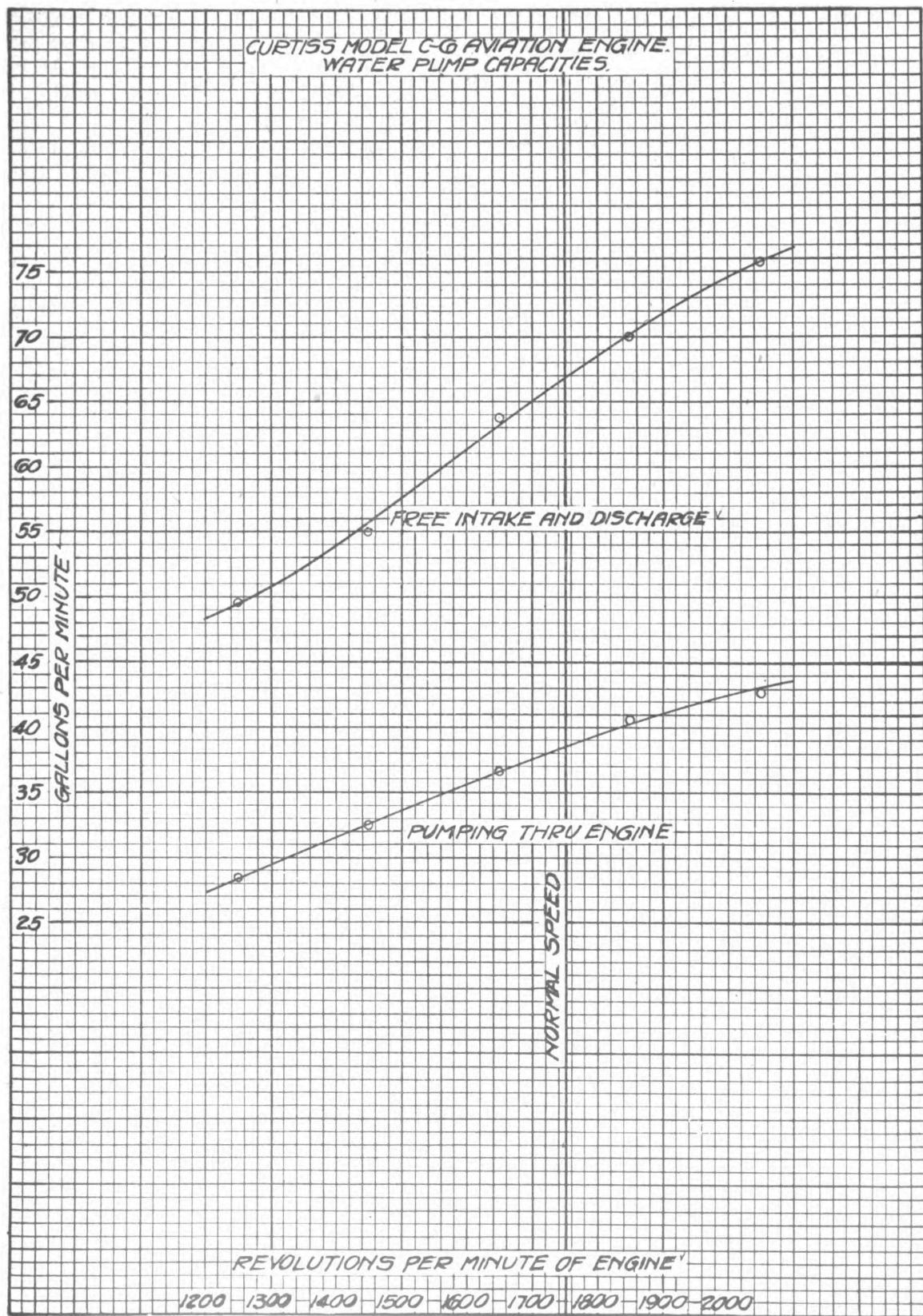


FIG. 24.

